

Why Choose an Inquiry-Based Approach?

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Reforming Science Education

During the 1990s, a number of science education initiatives were under way to reform high school science teaching to reflect strategies from the latest research and to enable more students to attain a higher level of scientific literacy. In 1996, the National Research Council published the National Science Education Standards [1] that summarized how the emphasis of many areas of science teaching should be changed to reflect these new initiatives. Other publications [2, 3] have also reiterated the need for educational reform strategies within the arena of science teaching. For example, it was noted in the National Science Education Standards that **LESS** emphasis should be placed on:

1. Transmission of teaching knowledge and skills by lectures.
2. Learning science by lecturing and reading.
3. Separation of theory and practice.
4. Individual learning.
5. Using assessments unrelated to curriculum and teaching.
6. Maintaining current resource allocations for books.
7. Textbook- and lecture-driven courses.
8. Broad coverage of unconnected factual information.
9. Science learning opportunities that favor one group of students.
10. Focusing on student acquisition of information.
11. Presenting scientific knowledge through lecture, text, and demonstration.
12. Asking for recitation of acquired knowledge.
13. Knowing scientific facts and information.
14. Activities that demonstrate and verify scientific content.
15. Investigations confined to one class period.
16. Individual process skills such as observation and inference.
17. Getting an answer.
18. Providing answers to questions about science content.
19. Individuals and groups of students analyzing and synthesizing data without defending a conclusion.
20. Doing few investigations in order to leave time to cover large amounts of material.
21. Concluding inquiries with the result of the experiment.
22. Private communication of student ideas and conclusions to the teacher.

And **MORE** emphasis should be placed on:

1. Inquiry into teaching and learning.
2. Learning science through investigation and inquiry.
3. Integration of science and teaching knowledge.
4. Collegial and collaborative learning.
5. Aligning curriculum, teaching, and assessment.
6. Allocating resources necessary for hands-on inquiry teaching.
7. Curriculum that includes a variety of components, such as laboratories emphasizing inquiry and field trips.
8. Curriculum that includes natural phenomena and science-related social issues that students encounter in everyday life.
9. Providing challenging opportunities for all students to learn science.

10. Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes.
11. Guiding students in active and extended scientific inquiry.
12. Providing opportunities for scientific discussion and debate among students.
13. Understanding scientific concepts and developing abilities of inquiry.
14. Activities that investigate and analyze scientific questions.
15. Investigations over extended time periods.
16. Using multiple process skills such as manipulation, cognitive, and procedural.
17. Using evidence and strategies for developing or revising an explanation.
18. Communicating science explanations.
19. Groups of students often analyzing and synthesizing data after defending conclusions.
20. Doing more investigations in order to develop understanding, ability, values of inquiry, and knowledge of science content.
21. Applying the results of experiments to scientific arguments and explanations.
22. Public communication of student ideas and work to classmates.

Clearly, the more active students are in their own science education, as outlined by the Standards above, the more scientifically literate each student will become. Having students probe for answers to scientific questions will lead to a deeper understanding of scientific concepts than if the teacher simply provides students with the scientific facts alone. Applying this rationale to AP Environmental Science labs should produce more environmentally literate students. The more we can get students involved, the better prepared they will become in understanding environmental science. At the same time that new teaching strategies were being assessed for improving science education, other initiatives were underway in designing and implementing problem-based curricula that were complementary to the National Science Education Standards. A monograph was published by the North American Association of Environmental Education [4] in order to add to "the ongoing dialogue about how we can better promote environmental understanding and problem-solving skills in our citizenry." Curricula have been produced and introduced in both middle and high schools that pose an environmental problem that students have to solve by using inquiry-based strategies [5, 6]. A framework for problem-solving inquiries has also been suggested for use across the science curriculum with gifted middle school students [7]. As more and more science teachers introduce inquiry-based approaches into their classrooms across the country, we shall see an increase in the number of articles relating to inquiry-based curricula in educational journals and magazines [8]. A growing number of teachers are routinely incorporating experimental design as part of the lab experience for their students [9].

Introducing inquiry-based strategies not only into the classroom but also into the laboratory sections of science courses will help students enhance and develop their critical-thinking and communication skills. Incorporating such strategies within the framework of the lab and field activities of the AP Environmental Science course is in line with the latest standards for science education and also fulfills the criteria in the "Lab and Field Investigation" section of the Course Description in a meaningful and innovative way.

As most inquiry begins with a question, each lab should involve providing students with a question relating to a specific issue or topic for them to explore. The question can be either teacher- or student-generated. For example, I take my students to a pond on campus that they are familiar with. I ask them to comment about the pond and how it is connected to the surrounding area. During the course of this student dialogue, it becomes apparent to them that the pond has changed during their time at the school, as it now has much more aquatic vegetation in it than in previous years. The question I then pose to them is, "What is causing this observation?" Often one of the students asks this question before I do, to which I respond, "That is a good question; how can we go about finding the answer?" To me, this is a much better approach to a lab activity than if I simply took the class down to the pond and had them conduct some water tests! The students feel empowered as they later carry out the experiments and field studies that they have designed to unravel answers to this real-life environmental problem! The students present and explain their findings to the whole class as we proceed with the investigation.

This type of pedagogical approach, where students have to think about a particular problem and choose a plan or strategy that they perform and check the outcome of, is similar to the steps involved in the scientific method. Students research the topic, produce a hypothesis, design an experiment to test the hypothesis, analyze the collected data, and determine if their hypothesis was confirmed. They are acting much like a real research scientist would!

There are benefits for both teacher and students when using an inquiry-based approach [5, 6] as described below:

Examples of what teachers could gain from an inquiry-based methodology

- Focus on cooperative learning.
- Learn how to identify, plan, and structure a problem having environmental impact.
- Develop individual, problem-based labs that best suit their own schools' needs.
- Learn how to utilize the local surroundings for economical field trips.
- Implement experimental design approaches for conducting science labs and student research.
- Participate in worthwhile, hands-on activities and field trips with their students.
- Learn how to empower students to become more active in the learning process.
- Enjoy an exciting methodology for teaching science labs!

What could students get from inquiry-based learning?

- Develop critical-thinking skills.
- Become actively involved in the learning process.
- Experience excitement about studying science because rigorous problem-solving can be enjoyable!
- Work together as part of a problem-solving team and come to an understanding that shared efforts and abilities produce the best team result.
- Increase self-esteem from the fact that their own individual effort contributes positively to the team solution of the problem.
- Develop problem-solving skills that can be applied to other areas in their lives and to other academic disciplines.
- Learn how to design an experiment and carry out scientific research including observations and data handling.
- Learn how to organize and interpret scientific information.
- Make written and oral presentations of the results of their research.
- Increase understanding of basic scientific knowledge through deductive reasoning rather than passive learning techniques.

The advisory group concluded that such approaches should be implemented into the first set of AP Environmental Science labs that are posted on the Web sites of the College Board and the Environmental Literacy Council. Such an inquiry process in labs enables students not only to investigate and understand specific content material but also to investigate TO understand!